A HISTORICAL PERSPECTIVE OF SUGAR MAPLE DECLINE WITHIN ONTARIO AND OUTSIDE OF ONTARIO

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A Historical Perspective of Sugar Maple Decline Within Ontario and Outside of Ontario

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1. Introduction

A disorder of Sugar Maple (Acer saccharum) trees in North America has been recognized whereby a general recession in health and, frequently death, of trees occurs. The condition has been variously termed maple decline, maple decadence, maple deterioration, maple blight and maple dieback. No single cause of the condition has been identified and it may be a non-specific response of the tree to a variety or combination of agents. Recently, consideration has been given to the possibility that acidic deposition or pollutants transported over long distances could be involved. The current report summarizes the published data for maple decline in an attempt to place a historical perspective on the situation within the Province of Ontario as well outside the province.

Symptomatology of the disorder has been described by Griffin (48). Based on his description, as well as other more recent observations, the symptoms most often reported are:

1) sparse foliage on trees with leaves often dwarfed and exhibiting interveinal necrosis;

2) chlorosis and marginal leaf scorch;

3) early leaf discolouration followed by premature leaf fall;

4) progressive deterioration of young twigs and branches of increasing size;

5) decline of part or almost all of the leaf crown;

6) low starch levels; and

7) death and/or recovery of affected trees.

Various causes of sugar maple decline have been investigated and some have apparently been identified although the majority of cases remain unresolved. Some of the causes include insect defoliation, diseases, climatic conditions, pollutants, and mechanical injury. The causes are frequently inter-related and may act synergistically to the detriment of the tree.

2. Sugar Maple Decline within Ontario

Sugar maple decline in Ontario was first reported from the Ottawa-Huron and Algoma extension forest region and since then numerous episodes have been reported throughout the Province. The heaviest concentration of decline reports has originated from the Sudbury-Parry Sound-Muskoka-Simcoe-Grey district/counties. The degree of reported damage has been highly variable, ranging from light to severe. Appendix A summarizes reports of sugar maple decline in Ontario from 1947 to 1985.

A total of 102 reports or cited causes of decline were examined. Unfortunately, the contents of each report were not standarized as to location, severity, symptoms, primary or secondary cause and therefore, a complete picture of the situation could not be developed. The remainder of this section of this report was prepared within these limitations.

The primary cause of sugar maple decline is largely unknown. Eighteen per cent (19 reports) of the reports listed the cause of the decline as unknown.

Total climatic conditions including drought, frost, lightning, low winter temperatures, exposure to winds and wet periods followed suddenly by sunny windy periods accounted for 18 per cent of the reported instances of decline (Table 1). Drought alone accounts for one third of the reported instances of decline in this category. Road salt and herbicide contamination accounted for 6 per cent and mechanical injury and cultural practices an additional 4 per cent each of the incidents reported.

Insect defoliation is represented in 23 per cent of the cases of sugar maple decline in Ontario. The predominant defoliator of the eight identified insects is the Forest Tent Caterpillar. Since the inception of the Forest Insect and Disease Survey in 1936, four major outbreaks of the forest tent caterpillar have been recorded in Ontario: in the mid to late 1930's; 1948-56; 1960-66; and 1973-78. These outbreaks clearly illustrate a pattern or cycle of defoliation which occurs periodically and which continues for four to eight years. The duration of these outbreaks is controlled by a species of fly which is parasitic on the caterpillar larvae.

Armillaria mellea (shoe string) root rot is the most prevalent of the disease organisms which have been identified with about 20% of the reported cases. Other associated disease organisms include a variety of fungi, including saprophytes, wilts, and cankers. Diseases such as maple leaf anthracnose have also been identified.

Improper woodlot management such as overcutting, understocking, overtrapping and pasturing of cattle in woodlots was listed in 4 reports. Acidic precipitation and other causal agents of maple decline are represented in 2 and 5 reported cases respectively.

From the published data, it becomes apparent that there is no individual or distinct cause of sugar maple decline in Ontario. In fact, historically there have been more instances where the cause of maple injury is unknown than from any single identifiable agent. Inciting factors such as drought and defoliating insects are important agents which greatly weaken the tree, thereby predisposing the tree to secondary pathogens such as Armillaria root rot or the maple stem boring insect. If the tree is unable to withstand the stresses of these agents, it will begin to exhibit the symptoms of decline.

Of the reports examined, 65 of reported problems have taken place since 1975. It is not clear whether this actually reflects a dramatic increase in the problems or whether it is due to the reporting procedure.

The cited problems occur throughout Southern Ontario and injuries were not restricted to any one area. Extensive defoliation of maple by insects was recorded in the Parry Sound, Algonquin Region east of Georgian Bay in the mid to late 1970's in the same area where the Ontario Ministry of the Enviroment conducted studies of maple decline in 1984. It would be necessary to examine the notes and records of the original investigators to determine more specifically the location and severity of the individual problems. Such examinations would need to be done on a woodlot basis to determine the casual relationship between insect attack and subsequent decline of affected maple trees.

3. Sugar Maple Decline Outside of Ontario

The first report of sugar maple decline outside of Ontario was made in 1913, in the northeastern United States. Subsequent to this a major observation of decline was made in Florence County, Wisconsin in 1957. Generally, sugar maple decline has been observed frequently throughout the northeastern United States and Quebec. Appendix B summarizes reports of sugar maple decline outside of Ontario during the period 1913 to 1985.

In areas outside of Ontario, the description of decline symptoms appears much more advanced and detailed. Generally, symptomatic trees are found in either open or closed stands and are of mature age classes, although declining trees of all ages and size have been reported. Symptoms of damage include: 1) progressive dieback of buds, twigs and branches from upper outer-most parts of the crown; 2) foliar chlorosis, necrosis, wilt and marginal leaf scorch; 3) low foliar nitrogen and calcium levels; 4) dwarfed foliage; 5) early leaf discolouration and premature leaf fall; 6) epicormic sprouting; 7) primary root necrosis; 8) greenish discolouration in sapwood and twig cross-section; 9) low starch levels; 10) reduction in growth rate; and 11) sudden or prolonged death.

The degree of damage has been highly variable ranging from patches of lightly affected trees to tree death over extensive areas. Eighty-seven cited causes of decline were examined (Appendix B).

Of these, 19% associated the decline with disease organisms with 5 reports listing Armillaria root rot as a problem. Seventeen percent of reported cases listed climatic conditions, predominantly drought, and other conditions such as frost, ice, and high winds as causal agents. Road salt contamination and herbicides were involved with 8 or 2% of reported cases respectively. Only 10% of examined reports noted insect defoliation as contributing to the decline of maple. In contrast to the Ontario situation, nematodes, nutrient deficiences and air pollution were identified also as contributing to maple decline. Analogous to reports in Ontario, unknown causes represented a substantial 12% of causal agents of maple decline. Other causes such as genetic differences and tree age also represent 12% of reported cases of maple decline. Of the total reported cases of sugar maple decline outside of Ontario; acidic precipitation, cultural practices, and mechanical injury appeared to play a less significant role.

4. General Discussion

One of the best reviews of sugar maple decline is that prepared by Westing (82). Although his review was published nearly 20 years ago, we have not made many significant strides towards solving the puzzle. The following information summarizes some of the results of investigations into the cause of the decline syndrome.

A significant portion of the investigations of declining maples have implicated road salt with the poor state of roadside trees (1,50,59,60,73,75,76,82). Affected trees had higher than normal sodium levels and reduced growth (73). Scorching of leaf margins were attributed to chloride accumulation (1). Guttay (50) and Spitko et al. (78) were able to demonstrate that dieback of maple trees was associated with decreased development of endomycorrhizae. A proposal to apply gypsum to prevent salt injury through a process termed "soil desalinization" was made by J.M. Rubens (75) but no data was provided to substantiate the effectiveness of the treatment.

Insects have been identified as inciting agents of the decline of sugar maple. The decline situation in Wisconsin in 1957 had been preceded by 2 or more years of feeding activities by two species of leaf

rolling insects and a webworm (61). In Northeast USA, decline is frequently followed by outbreaks of the Saddled Prominent caterpillar which defoliates the trees (80).

Repeated defoliation causes a decline in vigor of affected trees which have lower starch and higher sugar content than unaffected trees (55). Houston (58) reported that changes in root chemistry of defoliated sugar maple stimulated the growth of Armillaria mellea and increased the rate of infection of the tree roots by this fungus.

Maple trees of low vigor appear to be more subject to attack by the Sugar Maple Borer (Glycobius speciosus) than trees of better health (79).

Armillaria mellea has been identified as a root-invader of trees which have been subjected to prior stresses such as defoliation (54, 55). The taxonomic status of this fungus is currently under review and may in fact represent a complex of several species, a situation which does little to aid the sorting of pieces of the decline puzzle.

Other species of fungi have been isolated from stem and root tissues of symptomatic trees, however, they tend to be saprophytes or weak parasites. Several authors have listed species of Steganosporium in this regard. Drilias et al. (45) have attributed Fusarium spp and a Phytophthora spp causing basal canker and collar rot respectively, as the agents responsible for urban maple decline in Wisconsin.

In contrast, Kessler and Anderson (57) discounted the involvement of wood streaking fungus Ceratocystis coerulescens in the decline of maple in the Lake States.

At least five reports have examined the role of nematodes in the decline of sugar maple (43,53,54,74,82). Although several genera of nematodes were found, the one encountered by all investigators was Xiphinema. Di Sanzo (43) demonstrated the feeding and reproduction of the species on sugar maple. Other species commonly encountered included Hemicyclophora, Tylenchus, Tylenchorynchus and Criconemoides. Only one author (43) considered nematodes as a possible major cause of maple decline.

Although drought stress has been recognized as a major inciting factor in the decline of maple trees, only Banfield (2) has attempted to document this role. The moisture stress could result from low precipitation rates, especially during the growing season, shallow soil, root injury, loss of ground cover and leaf litter, compaction of soil and exposure of the trees to conditions of excessive evapotranspiration. Griffin (48) considered that dieback in Ontario woodlots was mainly related to overcutting of the stands leaving them understocked and exposed. Also, pasturing of cattle was common. Both of these activities could fit into the drought stress conditions outlined by Banfield.

Nutritional status of sugar maple trees has been implicated in the decline syndrome. Mader and Thompson (63) examined a number of tree stands and concluded that foliar nitrogen was low in three stands exhibiting crown decline symptoms and reduced growth rates. Deficiences were corrected by fertilizing during a drought period when nitrogen availability and uptake would have been restricted. Westing (82) cites other reports of reversing decline with various fertilizers. By contrast, following injection of urea into the soil beneath declining trees, Rich and Walton (73) failed to obtain a favourable response of the trees. On high pH soils (pH 7.1 to 8.0) in Michigan, Kielbaso and Ottman (58) were able to partially reverse decline symptoms with applications of manganese. They concluded from this response that at least some maple declines could be the result of manganese deficiency.

5. Summary

A review of the literature indicated that the decline syndrome affecting sugar maple has been known in North America since the early 1900's. No single cause of the decline has been identified although many different factors could be involved in various combinations. It appears likely that the decline is a slow-developing, non-specific response to one or more inciting agents, primarily defoliation by insects and by drought. If the actions of the inciting agents are sufficiently severe or prolonged, trees already subjected to predisposing agents such as low soil fertility,

soil compaction or air contaminants, could be seriously weakened. In this weakened state, the trees are vulnerable to secondary agents such as bark beetle attack and root rot.

The current situation of maple decline in Ontario fits with this pattern. It remains to be demonstrated how important anthropogenic stresses are in the sugar maple decline syndrome.

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APPENDIX A

HISTORICAL PERSPECTIVE OF SUGAR MAPLE DECLINE WITHIN ONTARIO

YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1947-48	Ottawa-Huron and Algoma Extension Forest region	74% of 606 sampled trees Incidence and volume of decay increased progressively with age and diameter	Frost cracks Wood discolourations	28 fungi associations Most important fungi associations were: Armillaria mellea Polyporous glomeratus	71
1952	Grey County			Unknown	48
1954	Pembroke, Parry Sound, North Bay, and Sault St. Marie Districts; Haliburton, Simcoe, Perth, Dufferin, Wentworth, Peel and Norfolk Counties	High infection levels	Trees of all ages affected, with older trees growing on poor sites more symptomatic Plantations much more vulnerable than natural stands	Root Rot (Armillaria mellea)	4
1954	Parry Sound and Sault Ste. Marie Districts; Grey, Dufferin, Simcoe, Norfolk, and Haliburton Counties			Frost, lightning and drought scars with two fungi associations (a) Fomes connatus (b) Hypoxylon - canker forming fungi	4
1955	Rideau, Tweed, Sudbury, Sault Ste. Marie, North Bay, Lake Simcoe Dists.		Early discolouration and premature leaf fall	Drought	5

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YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1958	Southwestern Ont. (349 woodlots in 24 counties, including Grey and Bruce Counties)	26% unaffected, 52% lightly affected, 12% moderately affected, 10% severely affected	Sparse foliage on trees with leaves often dwarfed and exhibiting interveinal necrosis Marginal leaf browning followed by premature leaf fall Premature fall colouration Death of young twigs followed by dieback of part or all of the crown Dieback limited to trees over 6 in. d.b.h.	Overexposure in stands from overcutting and under stocking Pasturing of woodlots, especially during dry spells	48
1958	Southwestern Ont.	272 woodlots exhibited symptoms, 67 woodlots exhibited no symptoms	Interveinal chlorosis, marginal browning, or colouration striking fall colours	Unknown	6
	Northern part of Lake Simcoe Dist. and part of Lake Erie Dists.	Most severe symptoms	Complete browning and death of leaves, with premature leaf fall Death of young twigs followed by death of part or all of the crown Killing of the leader at an early stage on both younger and larger trees		
1959	Southwestern Ont. Grey and Bruce Counties	Most seriously affected stands of survey		Unknown	7
1960	Southwestern Ont.		Rapid dying of individual branches with a pronounced reddening of foliage on the affected branches	Primary cause: unknown Secondary cause: saprophyte (Steganosporium pyriforme)	8

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YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1961	Southwestern Ont.		Early fall-type colouration Recovery of some of the trees in sample plots established in 1958	Unknown	9
1960-66	Main concentrations in Northwestern, Northeastern Ontario	Light to severe	Defoliation	*Forest Tent Caterpillar (Malacosoma disstria)	13
1963	Southern Ontario (along highways, secondary roads, and streets in in urban areas)	Severe	Peeling of bark from main branches Dieback of large crown sections Symptomatic trees dead within 2 or 3 years	Primary Cause: Adverse climatic conditions Secondary Cause: Fungal Associations - Ganoderma applanatum - Armillaria mellea - Hypoxylon sp.	11
1964	Roadsides in Lake Huron and Lake Simcoe Dists.		Foliage discolouration withering and premature defoliation	Induced by a combination of bright sunlight, high temperatures and drying winds following periods of wet weather (Leaf Scorch)	12
1964	Roadsides in Aylmer, Fergus, Lindsay, and general throughout Lake Simcoe and Tweed Dists.	75% to 100% of trees showing signs of disease	Damage highest on mature trees	Drought, low winter temperature with deficient snow cover Chemicals used to control dust, weeds and ice (sodium chloride) Age of tree and changes in water table from road construction	12

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YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1965	Roadsides in: Kemptville Dist. Lindsay Dist. Lake Huron Dist. Lake Simcoe Dist.	% of trees showing signs of disease: 6% 23% 45% 66% (62% mortality) Overall mortality 7%	Damage highest on mature trees	Unknown	13
1965	Shade and roadside trees in Lake Huron, Lake Simcoe and Pembroke Dists.	50% foliar damage	Foliar discolouration, premature defoliation	Climatic condition (Leaf Scorch)	13
1965	Peck Twp, Algonquin Region Great Duck Island, Lake Huron North of Sault St. Marie (Hilltops and ridges throughout 8 twp.)	80% over 900 acres Moderate to severe over 2000 acres Severe	Defoliation	* Bruce Spanworm (Operophtera brucata)	13
1967-70	Georgian Bay Area; Lake Huron and Lake Simcoe Dists.	25% damage in 13% of trees surveyed in 3 observations plots	Defoliation Twig mortality Stands seldom defoliated severely more than 1 yr.	Saddled Prominent Insect (Heterocampa guttivitta)	15
1968	Southern Ont. (roadsides)			Abiotic condition	14

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HISTORICAL PERSPECTIVE OF SUGAR MAPLE DECLINE WITHIN ONTARIO

YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1971	Niagara Peninsula		Affected leaf portions turned brown to black, then withered; unaffected portions remained green Refoliation by mid-summer	Drying effect of high wind in late May	16
1971	Niagara Peninsula (Port Maitland Area)	Light to severe over a 40 mile radius More severe in the upper portions of trees, on the southwest sides of affected trees and on young, succulent leaves not fully expanded	Water-soaking of the intercostal and marginal portions of affected leaves Irregularly shaped injured portions dried to tan-coloured necrotic areas	Sudden exposure of foliage to bright sunshine and high winds following a wet, cloudy period (Late-Spring Leaf Scorch)	62
1972	Lindsay and Lake Simcoe Dists.		Dead branches	Primary cause: unknown Secondary cause: canker (Steganosporium ovatum)	17
1973	Between Georgian Bay and Pembroke; and Espanola - Sudbury - North Bay	Moderate to severe	Defoliation	* Forest Tent Caterpillar	18
1975	Parry Sound and Muskoka Dists. Minden and Bancroft areas	Moderate to severe	Defoliation Refoliation by mid-July	* Forest Tent Caterpillar	19
	Eastern Ont.	10 fold increase from 1974 Moderate to severe			
	Central Region	Moderate to severe			

APPENDIX A (Cont'd)

HISTORICAL PERSPECTIVE OF SUGAR MAPLE DECLINE WITHIN ONTARIO

YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
	Southwestern Region	Moderate to severe over 1000 ha. from 230 ha in 1974			
1975	Arran Twp.		Heavy infections on dead branches	Branch Canker (Stegonosporium ovatum)	20
1975	Scattered throughout Southwestern Ontario (not observed in undisturbed woodlands)	Light to severe	Leaf scorch, curled and stunted leaves, and premature shedding of leaves Dying branches in crown and eventual mortality Progressive deterioration	Salt and herbicide application Road rebuilding resulting in soil damage and stem injury	20
1975	Southwestern Ontario (shade trees)	Light to severe	Leaf scorch and premature shedding of leaves Progressive deterioration	Elevation, drought, herbicides Mechanical injury to root and stem and soil compaction.	20
1976	Algonquin Region and north and east of Georgian Bay	Severe over 20,000 km^2	Defoliation	* Forest Tent Caterpillar	21
1976	Western part of Lanark County	Severe over 160 km^2	Defoliation	* Forest Tent Caterpillar	22
1976	Northern Huronia Dist. Town of Lindsay	Moderate to severe	Defoliation	* Forest Tent Caterpillar	
1976	Adjala Twp. Huronia Dist. Cambridge and Niagara Dists.	90% of maple population suffered light damage	Defoliation of 15 metre high trees	Leaf Anthracnose of Maple	23

APPENDIX A (Cont'd)
HISTORICAL PERSPECTIVE OF SUGAR MAPLE DECLINE WITHIN ONTARIO

YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1976	Owen Sound and Wingham Dists.	Severe	Leaves turned black to brown and withered; unaffected portions remained green	Frost	24
1977	Owen Sound Dist.	Light to severe on few trees in 12 ha. patches	Defoliation of trees of all sizes classes usually in patches that are more prevalent in stand interiors. Rapid crown deterioration. Premature separation of bark	Forest Tent Caterpillar *Armillaria mellea* plays a secondary role	25
1977	Southern Ontario Survey (rural woodlots, roadsides and urban settings)	Note: 5% branches dead = healthy 20% branches dead = severe Woodlots - 68% healthy, 5% severe Roadsides/Urban - 56% healthy, 46% severe	Crown deterioration	Unknown	25
1977	Algonquin Region (19 rural, urban and woodlot sites)	Note: Crown Class 1 = healthy; 2 = 20% crown dead; 3 = 40% of crown dead; 4 = 60% of crown dead Crown Class: 1 + 2 / 3 + 4 Urban: 81% / 19% Rural: 81% / 19% Woodlot: 97% / 3%	Crown deterioration Presence of numerous organisms	Primary cause: unknown Secondary cause: foliage, stem, root, and wilt diseases; and climatic conditions	26
1977	Ottawa Kemptville Merrickville	Light to moderate	Branch deterioration Leaf chlorosis	*Verticillium* Wilt Canker (*Cytospora chrysosperma*) Saprophyte (*Stegansporium ovatum*)	27

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HISTORICAL PERSPECTIVE OF SUGAR MAPLE DECLINE WITHIN ONTARIO

YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1977	Simcoe, Wingham, Owen Sound and Chatham Dists. Cities of London St. Thomas, Aylmer and Sarnia - Windsor area	Light to severe	Mainly found in open grown urban settings Leaves show light brown spots and infection progresses from outer leaf towards centre Premature leaf fall	Leaf anthracnose of maple	28
1977	Central, Southwestern Algonquin and Eastern Region	Severe over 33,800 km^2	Defoliation	* Forest Tent Caterpillar	25
1978	Freeman Twp. Parry Sound Dist.	Light to severe over 20,000 acres	New growth exhibited brown necrotic spotting between dead upper parts of crown with relatively healthy foliage Small dead twigs were noted in the centre of new growth	History of insect defoliation Leaf spot (Phyllosticta)	65
1978	Owen Sound Dist. (2749 sugar maples examined)	% of all branches dead / % of all sugar maple trees affected: 0-5% — 70.9%; 6-20% — 17.3%; 21-40% — 3.2%; 41-60% — 2.1%; 60% dead — 1.6% / 4.9%	Crown deterioration	Unknown	29
1978	Owen Sound, Parry Sound, and Muskoka Dists.	15,000 ha with 80% mortality	Defoliation in patches	Forest Tent Caterpillar	30
	Owen Sound Dist. Survey	30% maple mortality 50% of affected trees had 20% of branches dead			

APPENDIX A (Cont'd)
HISTORICAL PERSPECTIVE OF SUGAR MAPLE DECLINE WITHIN ONTARIO

YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1978	Medonte Twp. Simcoe Dist.	Severe over 400 ha.	Semi-mature and mature trees affected	Unknown	31
1978-79	Muskoka, Owen Sound, Parry Sound, Wingham Dists. (29 sites)	Healthy to severe	Trees with 3% starch content tended to improve or remain static with regard to branch mortality, conversely for trees with less starch	1973-78 Forest Tent Caterpillar Infestation	49
1980	Throughout Southern Ont.	Light to severe	In August, premature leaf colouration and leaf fall on few branches Twigs and branches of increasing size continue to die	Variety of infectious and non-infectious factors Heavy thinning causing overexposure	3
1980 (preliminary impact analysis of 1977 and 1978 forest tent caterpillar kill)	Algonquin and Southwestern Regions	Light to severe over 25,000 ha. Trees with over 40% of crown dead continued to decline in 1980	Defoliation Crown, branch and twig deterioration	Primary cause: 1973-78 Forest Tent Caterpillar infestation Secondary cause: climatic conditions	32
	Parry Sound Dist.	Severe over 8,000 ha (25% sugar maple dead)			
	Owen Sound Dist.	Severe over 500 ha. (25% sugar maple dead)			
1981	Oxform Mills-Charleston Lake, Brockville Dists., Kingston Belleville area, Napanee Dist.	30 to 70% of trees showing signs of disease		Unknown	33
1981	West of London, Southwestern Region		Sporadic crown and branch dieback	Unknown	33

APPENDIX A (Cont'd)
HISTORICAL PERSPECTIVE OF SUGAR MAPLE DECLINE WITHIN ONTARIO

YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1981	North Bay	Light to severe	Crown mortality, wilting of foliage between June and mid-August Majority of affected trees 7 to 20 years old and of ornamental use	Unknown	33
1981	Cockburn Island, Espanola Dist.	Several large patches of mortality		Unknown	34
1981	Smith Falls, Perth and Carleton Dists.	75% dead or dying	Small branches begin to die in upper most crown by late May, and throughout June Majority of crown and or tree dies In August, bark on main branches cracks, dries out and falls off	Primary cause: unknown Secondary organisms have been cultured	35
1981	Bedford Twp. Napanee Dist.	Severe over 20 km^2	Defoliation	* Maple Leaf Cutter (Paraclemensia acerifoliella)	36
1982	Wingham Dist. (roadsides)	Light to severe	Large green or red-brown anthracnose lesions occur along or between the veins, and often extend to the leaf margin	Leaf Anthracnose of Maple	36
1982	Awenda Provincial Park, Huron Dist.	Light to moderate	Defoliation	* Saddled Prominent Insect (Heterocampa guttivitta)	37

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YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1982	Southwestern (north), Algonquin (west), and North-eastern (south) regions	Damage up to 90% of the leaf over 100,000 ha.		Climatic condition (Leaf Scorch)	37
1982	Amabel and Keppel Twp. Owen Sound Dist, McNab Twp. Pembroke Dist.	Severe	Localized patches of dead leaf tissue, which later turns brown and dies Bud damage evident	Bright, dry, windy weather causes severe loss of water within the developing leaf that cannot be re-placed quickly (Maple Scorch)	36
1982	Pearce Provincial Park, Alymer Dist.	60% over 68 ha	Defoliation Skeletonizing	* Maple Trumpet Skeletonizer (Epinotia aceriella)	37
1983	Patterson, East Mills, Pringle, Nipissing, Gurd and South Hims-worth Twps, North Bay Dist.	25% over 80,709 ha	Skeletonizing	* Maple Trumpet Skeletonizer	38
1983	Temagami Dist.	40% over 180 ha.	Defoliation	* Greenstriped Mapleworm (Dryocampa rubicunda)	38
1983	Northeastern Parry Sound and northern Bracebridge Dist.	90% tree infestation with 25% foliar damage over 54,341 ha.	Skeletonizing	* Maple Trumpet Skeletonizer	39
1983	Tiny Twp, Huronia Dist.	Moderate over 10 ha sugar bush		* Pitted ambrosia beetle (Corthylas punctatissimus)	40

APPENDIX A (Cont'd)
HISTORICAL PERSPECTIVE OF SUGAR MAPLE DECLINE WITHIN ONTARIO

YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1983	Arthur Twp. Cambridge Dist. Wilmot Twp. Cambridge Dist. and Tiny Twp. Huronia Dist.	Moderate on occasional single trees Heavy in 1 ha pockets	Non-uniform defoliation	Primary cause: unknown Secondary cause: Armillaria Root Rot and 20 other fungi associations	40
	East Luther Twp. Camridge Dist.	Heavy throughout 4 ha. stand			
1983	Osprey, Collingwood, Amabel Eastnor, and Albemarle Twp. Owen Sound Dist.	40 to 50% over 600 ha.	Defoliation, particularly affected regeneration and smaller trees	* Maple Trumpet Skeletonizer	41
1983	Southwestern Ont. (urban and rural roadside settings)			Salt, root compaction and urban and highway development Unknown	41
1983	Southeastern Ont.		Branch and twig mortality Smaller than normal foliage and early leaf fall	Primary cause: unknown Secondary cause: drought conditions	42
1984	Muskoka and Parry Sound Dist. (7 woodlots) Thunder Bay (1 control woodlot)	Light to severe	Early leaf fall Sparse foliage on trees with leaves often dwarfed and exhibiting interveinal necrosis	Primary cause: 1976-77 Forest Tent Caterpillar defoliation Secondary causes:	64

APPENDIX A (Cont'd)

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YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
			Premature leaf discolouration and leaf fall Branch and twig dieback followed by dieback of part or all of the crown High amounts of soluble aluminum in soil Foliar chemical gradient with reduced elemental concentrations in tops of tree crowns Reduced incremental tree growth	Drought periods in spring of 1976, 1977 and 1983 Acidic precipitation Armillaria mellea Tree age and site management	
1985	Muskoka Dist.	90% affected	Premature leaf discoloration and leaf fall from upper most and outermost twigs Root decay, adventitious buds, bark peeling and heavy seed crops	Possible Acid Rain role	69
	Algonquin Region	75 acre sugar bush-600 dead trees in 3 years	Tree mortality		
	Ontario in general	Healthy to severe		Woodlot Management - overstocking - overtapping	

*Note: Indirectly attributable to sugar maple decline. Not able to identify as a primary or secondary cause of sugar maple decline.

APPENDIX B

HISTORICAL PERSPECTIVE OF SUGAR MAPLE DECLINE OUTSIDE OF ONTARIO

YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1913	Pennsylvania and New Jersey (ornamental trees)	Light to severe over one season Localized in many trees	Marginal necrosis and in some cases injury between the veins Defoliation of injured branches Most severe injury on south and southwestern facing foliage	Drought	51
			Defoliation, especially on northeast sides Large areas of marginal and between the veins necrosis Very small polygonal dead spots on foliage, without reference to margin or veins ("maculate")	Storm injury	
1926 (first reported 1915)	Northeastern United States		Sudden death of tree limbs one after another Slime-flux area on the diseased trunk and branch Green streaks in sapwood Small dark soft spots on bole of tree	Maple wilt (Verticillum)	47
1939	Pisgah National Forest North Carolina (drainage creeks)	60 trees dead or dying	Gray to reddish radial streaks and water soaked areas in the wood Foliage becomes progressively smaller and paler green each year, and death within 2 to 4 years from the first evidence of crown - thinning	"Sap streak Disease" (Endoconidiophora virescens)	52

APPENDIX B (Cont'd)

HISTORICAL PERSPECTIVE OF SUGAR MAPLE DECLINE OUTSIDE OF ONTARIO

YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1952-56	Northwestern Pennsylvania (mixed hardwood forest)	Light	Longitudinal/swellings and ridges on bark Cracked bark Dead branches, smaller curled leaves, and premature leaf discolouration and leaf fall Swelling predominantly on the lower 20 feet of bole	Sugar-Maple Borer (Glycobius speciosus)	79
1957-58	Florence County, Wisconsin	Moderate to severe over 1000 acres	Severe symptoms more prevalent in open stands, on upper slopes, and in the hardwood stands where sugar maple made up 50% of volume	History of insect defoliation - Leaf roller (Acerivorana) - Leaf roller (Aclerischalybeana) Armillaria Root Rot	61
	Iron County, Wisconsin	Light to severe in two patches: 0.5 acre and 0.9 acre			
	Ashland County, Wisconsin	Light to severe in three patches: 1 acre 0.3 acre and 1.2 acre	Branch dieback Foliar chlorosis and wilt Red-brown colouration of leaves Dwarfed foliage Epicormic sprouting Nematode species present in large numbers in the upper eight inches of soil	Climatic Factors - Frost damage after refoliation - 10 month period prior to severe mortality in 1957, precipitation was 8.3 inches below normal	
1957-58	Wisconsin, Michigan and Minnesota	Severe over 10,000 acres 1.5 million board feet of affected maple timber salvaged	Trees of all sizes and age class affected Trees die in stages, with one branch at a time dying out Crown dieback and light to severe defoliation Primarily open stand density and sugar maple composition	History of insect defoliation Many fungi and bacteria present Bud injury due to fall frost	77

APPENDIX B (Cont'd)

HISTORICAL PERSPECTIVE OF SUGAR MAPLE DECLINE OUTSIDE OF ONTARIO

YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1959	Upper Peninsula Experimental Forest Dukes, Michigan	Light (one tree)	Foliage never obtained more than one-half normal size but remained green all summer Dark greyish-brown, longitudinal streaking with occasional green and red streaking of the wood and buttress roots	Ceratocystis coerulescens	57
1959-60	Marathon Country Wisconsin-(6) 1/10 arce plots Florence county, Wisconsin- (5) 1/10 acre plots Iron county, Wisconsin- (4) 1/10 acre plots	Healthy to severely diseased stands	Symptoms resulting from nematode infection are similar to those found on maple blight and maple dieback trees Numerous nematodes species were found in the upper 8 inches of soil in both healthy and diseased stands	Primary cause: unknown Circumstantial evidence suggests nematodes may have contributed to the incidence of maple blight and dieback	74
1960-61	Ostego, Clinton, Allegany, Chautauqua, St. Lawrence, and Schuyler Counties, New York State	Light to severe 46% of symptomatic trees affected by Armillaria root rot	Necrotic roots larger than 3 mm diameter consisted of partial or completely rotted root ends Many fungi present on stem and root isolations High population of certain nematodes	Primary Cause: unknown Secondary cause: Armillaria root rot	54
1961	Vermont (roadside)		Greenish ring discolouration in twig cross-section	Primary Cause: Unknown Secondary Cause: Verticillium wilt Phytopthora cactorum	67

APPENDIX B (Cont'd)

HISTORICAL PERSPECTIVE OF SUGAR MAPLE DECLINE OUTSIDE OF ONTARIO

YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1962	Upper Michigan	1958-10% injury 1960-20.5% injury 1962-27.9% injury	Large trees affected more severely Sudden crown death-dead twigs and branches show up following year indicating crown injury during dormant season (1/4 to 1/2 crown destroyed) Dwarfed or chlorotic foliage Injury higher in heavily cut areas	Unknown	56
1962	Western, Central and Northern New York woodlands (seven plots)	Healthy to severe	Dieback of crowns Some primary root necrosis General growth reduction	Fungi: - Armillaria mellea - Cephalosporium - Pyrenochaeta - Cytospora Nematodes: - Hemicycliophora - Helicotylenchus platyrus - Xiphinema americanum 1951-54 Forest Tent Caterpillar epidemic 1948-60 high drought period Lower total foliage and soil nitrogen relationships in symptomatic trees	53
1962	Vallee Junction Beauce County, Quebec Quebec City, Quebec		Premature yellowing and redding of leaves Large wounds on roots, stem or branches, often well decayed occurred on the trees with most affected foliage	Primary Cause: Climatic factors - ice, snow, frost and sunscald. Secondary Cause: Armillaria root rot	10

APPENDIX B (Cont'd)

HISTORICAL PERSPECTIVE OF SUGAR DECLINE OUTSIDE OF ONTARIO

YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1963	Massachusetts (Roadsides and sugar bush trees)	Light to Severe	Undersized, chlorotic and sparse foliage. Leaves exhibit early colouration and fall prematurely Twigs and branches of the upper crown die Reduction in rate of growth Some trees die over a period of three to four years and others seem to be recovering Decline more apt in old trees than young and more prevalent in trees disturbed by man	Unknown	70
1963	Northwood, New Hampshire (Highway)	Severe	Premature foliar colouration, marginal leaf scorch, defoliation and and death of the tree	Primary Cause: high sodium from salt contamination Secondary cause: nematodes and drought	60
1964	Massachusetts (86 roadside and sugar bush trees)	Healthy to severe tree condition	Small, light green foliage and/or few to many dead limbs Higher salt concentration in leaves and sap in roadside trees than sugar bush trees Higher concentration of chloride than sodium in leaves and sap Defoliation	Primary Cause: Sodium Chloride Secondary Causes: High chloride concentration, not sodium, produce leaf scorch Genetic differences influence trees ability to accumulate/ transport sodium and chloride	1

APPENDIX B (Cont'd)

HISTORICAL PERSPECTIVE OF SUGAR MAPLE DECLINE OUTSIDE OF ONTARIO

YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1964	Western Massachusetts (21 stands)	Healthy to severe	Thin crowns, yellowing of crown, lack of foliage (particularly in upper portion), reduction of leaf size, reduction in radical growth rate, and progessive die-back of twigs and branches from upper out-most of crown Low foliage nitrogen and calcium levels	Primary cause: Unknown Secondary cause: nitrogen deficiency in soils	63
1964	Trois-Rivieres, Quebec (roadsides) Quebec City, Quebec Montmagny to Riviere-du-Loup, Quebec		Premature leaf fall Location of trees on poor sites	High winds in June and July may have favoured desiccation and scorch	12
1964-66	New England and Ohio (roadsides)		Chloride levels correlated significantly with damage ratings and several times higher than sodium levels Four year growth increments correlated with decline rating and chloride levels	Sodium Chloride	59
1965	Northeastern States (particularly among roadside and ornamental trees)	Light to severe Decline is most prevalent in the eastern and central portion of tree range Severe in central New England	Smaller paler leaves that may exhibit marginal necrosis Early leaf discolouration and drop	Secondary causes: Biotic Fungi and bacteria Insects and mites Nematodes Viruses	82

APPENDIX B (Cont'd)
HISTORICAL PERSPECTIVE OF SUGAR MAPLE DECLINE OUTSIDE OF ONTARIO

YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
			Dying of terminal twigs and branches, particularly in upper crown Reduction in growth rate and some root necrosis Sudden or prolonged death No reduction in sap quantity or quality, at least in milder stages	Abiotic Precipitation Temperature Nutrition Soil pollution Air pollutants Internal contributing factors Drought resistance Other resistance Tree age	
1965-66	Western Massachusetts (17 plots in 14 towns)	Healthy - 29% Moderate - 44% Severe - 27%	Leaf yellowing, leaf scorch and smaller leaves Severe case: at least one half of the crown or the whole tree defoliated by September end	Nematode (Xiphinema americanum) Drought	43
1965-66	University of Massachusetts - Lab observations and field studies (roadside trees, campus trees in compacted soil, and pasture swale trees)	Light to severe	Progressive marginal scorch, early colourations and premature leaf fall Few to no roots under highway pavement, extensive root deterioration from pedestrian soil compaction, and root damage from cattle tramping	Drought, inadequate soil moisture, high evapotranspiration, high air and soil temperatures, low humidity, and full exposure to sun and wind	2
1968	North-central New York	Light to severe	Defoliation Starch levels are 1/10 as high as non-defoliated trees and 1/3 as high as minimum starch levels in normal trees	Saddled Prominent Insect (Heterocampa guttivitta)	80

APPENDIX B (Cont'd)

HISTORICAL PERSPECTIVE OF SUGAR MAPLE DECLINE OUTSIDE OF ONTARIO

YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
			Root starch is severely reduced in severely defoliated trees that refoliated in the same season, (because of extensive physiological changes in food, hormone, and water relations) Light to moderate defoliated trees did not refoliate the same season-starch levels were equal to those in non-defoliated trees Armillaria mellea present		
1970	Rogers City, Michigan	Light to severe	Leaf chlorosis and necrosis Trees in a low state of vigor Premature leaf fall High soil pH-soil metal in an unavailable form thereby creating metal deficient soils	Manganese Soil Deficiency ("perturbation syndrome")	58
1972	Tring Junction-Beauce County, Quebec	25-40% crown decline in 100 acre stand		Fume damage	17
1972	Southeastern New Hampshire (roadsides)	Slightly affected trees exhibited 30% decrease in growth, moderately affected 60% decrease, and severely affected 70% decrease in growth (results of 4 yr shoot increment injury test)	Decreased shoot growth	Sodium Chloride (Salt)	76

APPENDIX B (Cont'd)
HISTORICAL PERSPECTIVE OF SUGAR MAPLE DECLINE OUTSIDE OF ONTARIO

YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1973	New England, New York, Pennsylvania and Lake States (shade, ornamental and roadside maples)			Sodium Chloride Age Herbicides Heat from pavement (Leaf Scorch) Mechanical injuries	55
1973	Northeastern States	Severe	Decline of starch reserves Increase of sugars (glucose, fructose) Bud break Defoliation-severe enough to elicit refoliation	Root rot (Armillaria mellea) Insect defoliation	
1974	Connecticut (highway locations)	Healthy to severe	Healthy maples have more root volume in upper 20 cm of soil Higher root concentrations of sodium and chloride in damaged trees High sodium and chloride in soils, reduced potassium and phosphorus in roots and reduced leaf calcium and magnesium	Road salt application	50
1974	Northeastern United States and South-eastern Canada (streetside trees)	Light to severe	Premature leaf colouration early leaf fall, reduction in leader and vertical terminal growth, reduction in leaf size, reduction in annual growth of twigs, marginal leaf scorch, abortion of terminal buds, marginal leaf necrosis, tufting and sparseness of	Road Salt	75

APPENDIX B (Cont'd)

HISTORICAL PERSPECTIVE OF SUGAR MAPLE DECLINE OUTSIDE OF ONTARIO

YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1977	Madison, Wisconsin (transplanted trees) Milwaukee, Wisconsin (transplanted trees)	69% of 633 surveyed showed one or more symptoms 34% of 123 surveyed showed one or more symptoms	Premature fall colouration, usually on one side of the tree or overall of the tree crown Small leaves, early leaf drop and loose bark at root collar	Transplanted trees: - collar rot (incipient canker) - Basal canker - Fungi (Fusarium spp, Phytophthora citricola) Cankers possibly caused by deep planting of seedlings	45
	Northwest of Madison, Wisconsin (naturally seeded woodland trees)	Healthy to severe	Dead branches High rootlet mortality and internal wood discolouration Deterioration of bark and wood in the root collar area - above and below soil line	Woodland trees: - Unknown	
1977	Vermont (5546 sugar maples in 91 sugar bushes)	Stand Condition Class (%) Excellent - 29.5 Good - 58.5 Fair - 11.0 Poor - 1.0 Dead tree data shows that 50% of dead trees died four or more years before survey	Defoliation Stem rot and leaf scorch more common in sugar bushes rated poor Sugar maple borer incidence on maple higher in poor sugar bushes Decreasing dbh and stocking with decrease of crown condition class	Primary Cause: Unknown Secondary Cause: Site Disturbances, Grazing, Rock Outcrop	66
1981-83	Bois-Frans Region-Eastern Townships, Quebec	Light to severe over 1,850,000 acres Maple syrup production down from 3 million gallons in 1981 to 2 million gallons in 1982	Defoliation Broken crowns, withering branchlets and barkless limbs Dried up summer buds Decrease in maple syrup production	Forest Tent Caterpillar Improper woodlot management - cattle grazing overtapping Root rot, fungi, cankers Climatic factors Air pollutants	68

APPENDIX B (Cont'd)

HISTORICAL PERSPECTIVE OF SUGAR MAPLE DECLINE OUTSIDE OF ONTARIO

YEAR	LOCATION	SEVERITY	SYMPTOMS	CAUSE	REFERENCE
1983-84	Beauce, Megantic, Frontenac, and Arthabaska Counties Southern Quebec (129 study sites)	Dieback ranged from 12 to 37%, based on eight sugar maple association forest communities	Typical dieback symptoms Improverished forest soil Decrease in rate of tree growth	Acid rain and air pollution	46
1984	Beauce, Megantic, Frontenac and Arthabaska Counties, Quebec	5 to 50% tree mortality	Progressive reduction of tree crown growth Premature leaf discolouration and leaf fall	Unknown	72
1985	Quebec	Mortality rate of 16%	Premature leaf discolouration and leaf fall from upper most and outermost twigs Root decay, adventitious buds, bark peeling and heavy seed crops	Combination of abiotic and biotic causes	69
1985	New Brunswick	Two sites: 4-5% mortality, with 40-50% of remaining trees showing signs of decline	Dead tips and secondary branches	Unknown	69
1985	Vermont	25% decline in above ground biomass in an unmanaged forest 50% decline in trees on a managed stand	Decrease in number of trees per acre with diameters smaller than one inch	Primary Cause: Acid Rain Secondary Cause: Multiplicity of problems	69

Table 1

Summary of Causal Agents Associated with
Sugar Maple Decline in North America

Causal Agent	Ontario		Outside of Ontario	
	No. of Reports	% of Reports	No. of Reports	% of Reports
Climatic Conditions	12	12	8	9
Drought	6	6	7	8
Forest Tent Caterpillar	12	12	2	2
Other Insects	11	11	7	8
Nematodes	-	-	5	6
Armillaria Root Rot	6	6	5	6
Other Diseases	15	14	11	13
Salt	3	3	7	8
Herbicide	3	3	2	2
Acidic Precipitation	2	2	2	2
Air Pollution	-	-	4	5
Cultural Practices	4	4	2	2
Nutrient Deficiency	-	-	4	5
Mechanical Injury	4	4	1	1
Unknown	19	18	10	12
Other	5	5	10	12
Total Reports*	102	100	87	100

*The total reports cited does not equal sum of reports in each category since more than one agent may be involved.

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*The Federal Government has carried out numerous annual insect and disease surveys in Ontario and other parts of Canada under different department agencies. In this bibliography, they are noted as FIDS (Forest Insect and Disease Survey), FIDSO (Forest Insect and Disease Survey in Ontario), SB-FIDCO (Survey Bulletin-Forest Insect and Disease Condition in Ontario) and, FIDCC (Forest Insect and Disease Condition in Canada).

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